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Power Distribution System for a Small Unmanned Rotorcraft

by Brian Porter and Gary Haas

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14. ABSTRACT

In quest of weight savings, several modifications were made to a Joker model unmanned rotorcraft. Battery power for various subsystems was consolidated in a custom box, and smaller gauge wiring was substituted for the original. The results included a 17% increase in flight time as well as logistics benefits from fewer batteries to be recharged.

15. SUBJECT TERMS

unmanned aerial vehicle, power distribution system, flight time extension, battery consolidation, airframe weight reduction

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1. Background

The Unmanned Vehicle Technologies (UVT) Branch of the U.S. Army Research Laboratory Vehicle Technology Directorate participated in testing at Redstone Arsenal, AL, with the aim to assess the capability to detect and track small threat unmanned air systems, in collaboration with personnel of Aviation and Missile Research, Development, and Engineering Center (AMRDEC) and the National Ground Intelligence Center. UVT provided a Joker unmanned rotorcraft, built by Neural Robotics, Incorporated, augmented by additional sensors and apparatus for wireless data collection and download. The Joker is a 3.5-hp electric drive helicopter powered by two 18-V, 8000-mAh lithium polymer battery packs. It has a 1650-mm main rotor diameter. The aircraft was originally designed as an aerial photography platform, but due to its inherent stability, it is being used for several different research areas such as autopilot research.

AMRDEC had requested the longest possible flight time with the additional payload, and UVT responded with the effort described herein.

2. Objective

The major objective of the effort was to reduce the weight of the craft. Weight in a rotorcraft directly affects the power required to keep the craft airborne, which, in turn, affects the energy required from the battery.

A secondary objective was to adjust the center of gravity (CG) of the craft. The power reduction from a shift in vehicle CG is twofold. The primary benefit comes from the rotorcraft expending less thrust by decreasing the main rotor moment arm about the CG. The secondary effect is derived from the drag profile of the rotor disk. At a larger CG offset, the rotor tip-path-plane has a larger cross section against the forward wind generating more drag. With a CG located closer to the rotor shaft, the main rotor does not need to tip as far forward to generate the desired moment balance about the CG. A lower drag profile thus requires less power to move the vehicle forward.

Another objective was to reduce the effort required of the one-man ground crew and the turnaround time on the ground.

3. Weight Reduction Modifications

The unmodified Joker uses three separate batteries for the electronics as well as two batteries which power the rotor/drive system. The three batteries are dedicated to one electronic element, with the native 11.2 V of the battery regulated to the voltage required by the component. The batteries are mounted along with electronics in a box mounted between the landing rails, underneath the airframe. For the Redstone test, three additional electronic elements were to be added. To prevent a weight gain, it was decided that a power distribution system, based on a single battery supplying power conditioned by voltage regulators, would be built to serve all the electronics. The single, 3800-mAh battery weighs 12.7 oz, compared to the total 31.7 oz of the three individual batteries of the original configuration. The additional electronics and housing add 9.5 oz, so the net gain over the stock configuration is 9.5 oz (see table 1 and figures 1 and 2).

The components and the batteries were packaged in an auxiliary box mounted to the front of the existing Joker electronics box, as shown in figure 3. Additional weight savings were realized by reducing the wire gauge of conductors in the original electronics box, from 12- to 18-gauge multistrand wire. This weight savings was not measured.

Table 1. Battery energy and weight.

Load Voltage (V)	Battery Energy (mAh)	Battery Weight (oz)
5	1100	5.9
9	3800	13.1
12	2200	12.7
Multiple	3800	12.7

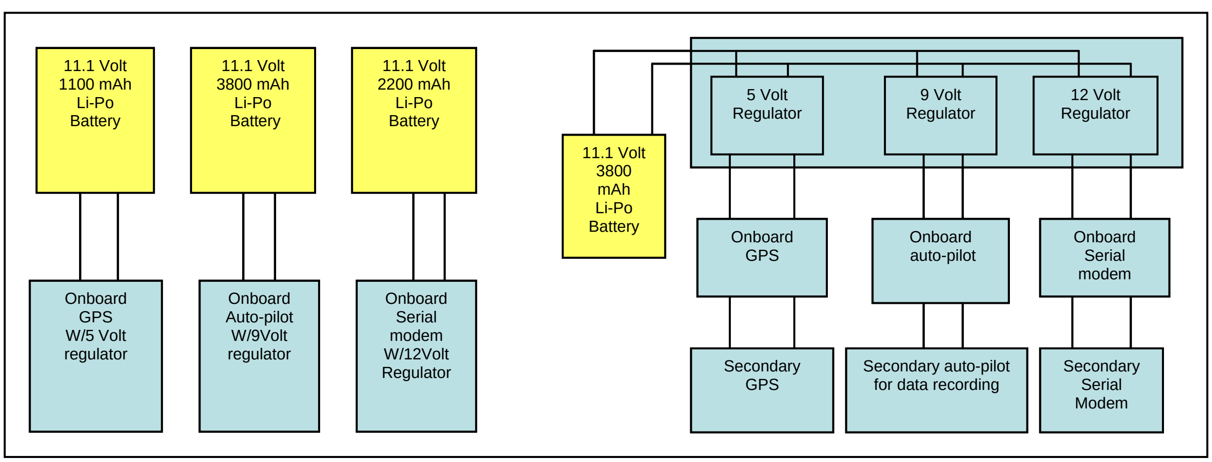

Figure 1. The original configuration, shown on the left, uses a dedicated battery for each component. The new configuration, shown on the right, uses a single battery operating through voltage regulators to power all components.

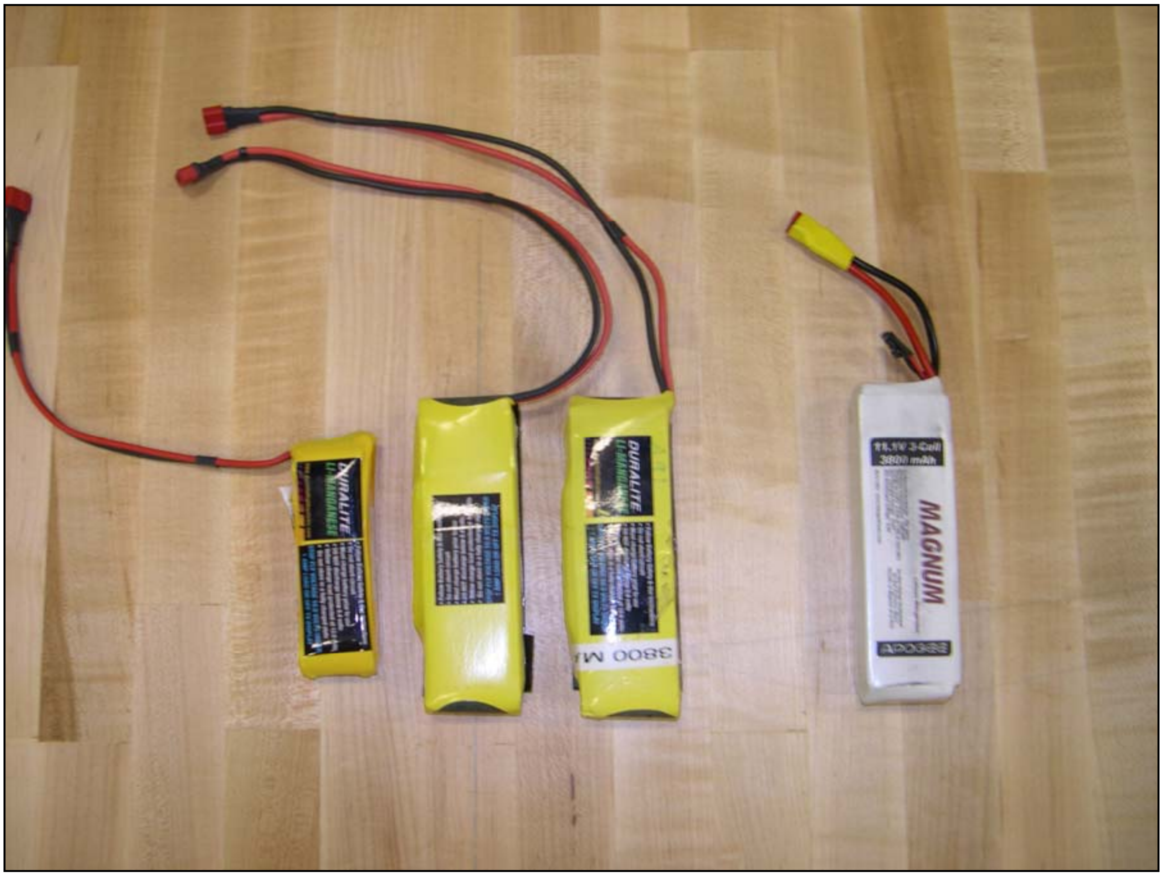

Figure 2. The three original batteries, in yellow weigh 31.7 oz. The single battery of the new configuration, in white, weighs 12.7 oz.

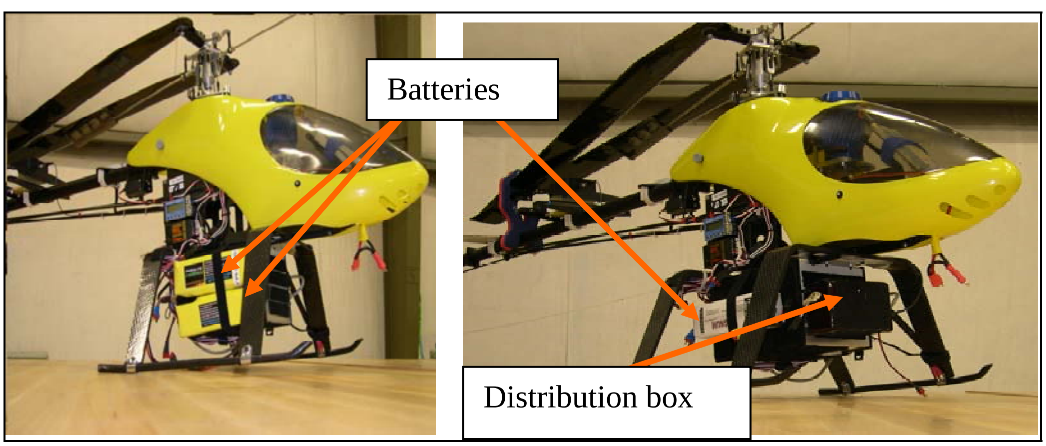

Figure 3. The original configuration is shown on the left. A third battery on the other side of the original electronics box is not visible here. The new configuration with a power distribution box is shown on the right.

4. Results

With the creation of the power distribution box, the weight of the aircraft (electronics [including special electronics for the test] and batteries) was trimmed by 9.5 oz from the 19.85 lb of the unmodified aircraft, for a reduction of roughly 3%. With the mass of the battery at its new location forward on the airframe, the CG was shifted to a better point directly below the rotor shaft, as shown in figure 4.

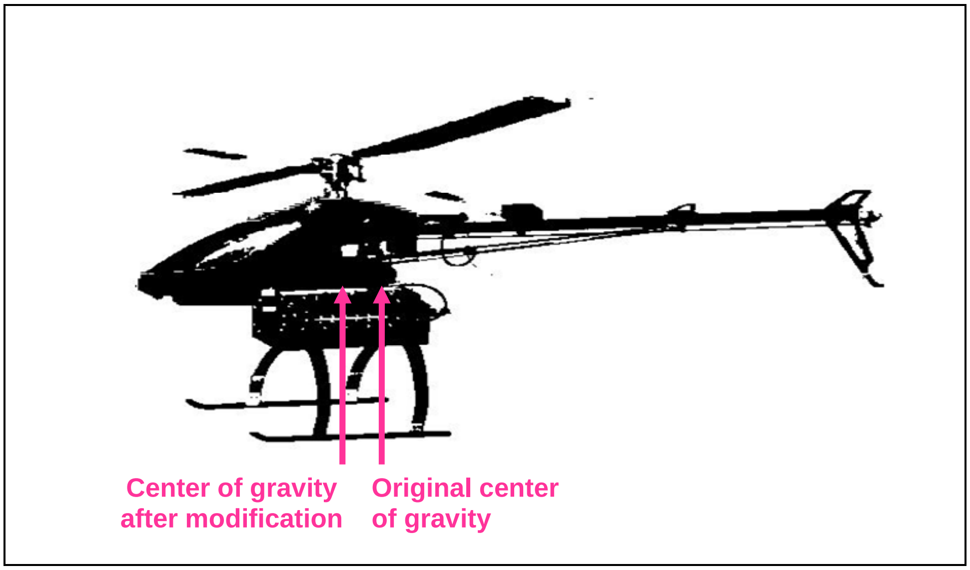

Figure 4. CG is shifted ~1.75 in forward.

The cumulative effect of the changes is evident in an increase in flight time from 12.4 min to 14.5 min, or 17%. The dramatic improvement in performance from the slight weight reduction can be attributed to the weight loss combined with the relocation of the CG.

An additional benefit of the new power distribution box is that only one battery, rather than three, needs to be charged by the ground crew, reducing the time to swap batteries and the number of chargers in the field. One charge typically lasts three flights.

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